AN

ACCOUNT

OF SOME

THERMOMETRICAL EXPERIMENTS;

CONTAINING,

I. Experiments relating to the cold produced by the evaporation of various fluids, with a method of purifying ether.
II. Experiments relating to the expanſion of mercury.
III. Deſcription of a thermometrical barometer.

By TIBERIUS CAVALLO, F. R. S.

Who was nominated by the Preſident and Council to proſecute Diſcoveries in Natural Hiſtory, purſuant to the Will of the late HENRY BAKER, Eſq. F. R. S.

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AN ACCOUNT, &c.

IT is at preſent well known, that by the evaporation of various fluids a ſenſible degree of cold is produced; and that by the evaporation of ether, which is the moſt volatile fluid we are acquainted with, water may be congealed, and the thermometer may be brought ſeveral degrees below the freezing point. But as various thermometrical experiments, which I lately made, have exhibited ſome new phenomena, and as I have contrived an eaſy and pleaſing method of freezing a ſmall quantity of water in a ſhort time, and in every climate; I think it not improper to give an account of theſe things in the firſt part of this lecture.

My firſt experiments were intended to diſcover, if poſſible, a fluid cheaper than ether, by the evaporation of which a degree of cold ſufficient for ſome uſeful purpoſe might be generated. But in this my expectation was diſappointed, as I found that ether was incomparably ſuperior to any other fluid, as the cold it produced was ſeveral degrees greater than that occaſioned by any other of the moſt volatile fluids whatever. Being, therefore, obliged to uſe ether, I endeavoured to contrive a method, by which the leaſt poſſible quantity of it might be waſted in the production of a degree of cold ſufficient to freeze water, and in this I met with ſucceſs. But before we come to the deſcription of this method, I

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ſhall briefly relate ſome obſervations made on the cold produced by the evaporation of other fluids beſides ether.

In a room, the temperature of which was 64° according to FAHRENHEIT's thermometer, and in which the air was gently ventilated, I obſerved the effects produced by various fluids when thrown upon the ball of a thermometer. The ball of this thermometer was quite detached from the ivory piece upon which the ſcale was engraved. The various fluids were thrown upon the thermometer through the capillary aperture of a ſmall glaſs veſſel, ſhaped like a funnel, and care was taken to throw them ſo ſlowly upon the bulb of the thermometer, that a drop might now and then fall from the under part of it; except when thoſe fluids were uſed, which evaporate very ſlowly, in which caſe it was ſufficient to keep the ball of the thermometer only moiſt, without any drop falling from it. During the experiment the thermometer was kept turning very gently round its axis, in order that the fluid uſed might fall upon every part of its bulb. This method I find to anſwer much better than that of dipping the ball of the thermometer into the fluid and removing it immediately after, or that of wetting the thermometer with a feather. The evaporation, and conſequently the cold produced by it, may be increaſed by ventilation. *viz.* by blowing with a pair of bellows upon the thermometer; but this was not uſed in the following experiments, becauſe it is not eaſily performed by one perſon, and alſo becauſe it occaſions very uncertain reſults.

With the above deſcribed method I began to examine the effects of water, and found, that the thermometer was brought down to 56°, *viz.* 8° below the temperature of the room in which the experiment was made, and of the water employed.

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This effect was produced in about two minutes time, after which a larger continuation did not bring the mercury lower.

By means of ſpirit of wine the thermometer was brought down to 48°, which is only 16° below the temperature of the room, and of the ſpirit employed. When the ſpirit of wine is highly rectified, the cold produced by its evaporation is certainly greater than when it is of the common ſort; but the difference is not ſo great as one, who never tried the experiment, might expect. The purer ſpirit produces the effect much quicker.

Uſing various other fluids, which were either compounds of water and ſpiritous ſubſtances, or pure eſſences, I found that the cold produced by their evaporation was generally in ſome intermediate degree between the cold produced by the water and that produced by the ſpirit of wine.

Spirit of turpentine brought the thermometer only 3° lower than the temperature of the room; but olive oil and other oils, which evaporate either very ſlowly or not at all, did not ſenſibly affect the thermometer.

Willing to obſerve how much electrization could increaſe the evaporation of ſpirit of wine, and conſequently the cold produced by it, I put the tube containing the ſpirit into an inſulating handle, and connected it with the conductor of an electrical machine, which was kept in action whilſt the experiment was performed; by theſe means the thermometer was brought down to 47°. Having tried the three mineral acids I found, that inſtead of cooling they heated the thermometer, which effect I expected; ſince it is well known, that thoſe acids attract the water from the atmoſphere, and that heat is produced by the combination of water and any of them. The vitriolic acid, which was very ſtrong and tranſparent, raiſed the

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thermometer to 102°; the ſmoaking nitrous acid raiſed it to 72°; and the marine acid raiſed it to 66°; the temperature of the room, as well as of the acids, being 64°, as mentioned above.

The apparatus which I contrived for the purpoſe of uſing the leaſt poſſible quantity of ether in freezing water, &c. conſiſts in a glaſs tube, terminating in a capillary aperture, which tube is to be fixed upon the bottle that contains the ether. Fig. 1. of the annexed drawing exhibits ſuch a tube, round the lower part of which, *viz.* at A ſome thread is wound, in order to let it fit the neck of the bottle. When the experiment is to be made, the ſtopper of the bottle containing the ether is removed, and the above mentioned tube is fixed upon it. The thread round this tube ſhould be moiſtened a little with water or ſpittle before it is fixed on the bottle, in order to prevent more effectually any eſcape of ether between the neck of the bottle and the tube. Then holding the bottle by its bottom FG (fig. 2.) and keeping it inclined as is ſhewn in the figure, the ſmall ſtream of ether iſſuing out of the aperture D of the tube DE, is directed upon the ball of the thermometer, or upon a tube containing water or other liquor that is required to be congealed.

Ether being very volatile, and having the remarkable property of increaſing the bulk of air, does not require any aperture, through which the air might enter the bottle, in proportion as the ether goes out: the heat of the hand is more than ſufficient to force the ether in a ſtream from the aperture D.

After this manner, throwing the ſtream of ether upon the ball of a thermometer in ſuch quantity as that a drop of ether might now and then, for inſtance every 10 ſeconds, fall from the under part of the thermometer, I have brought the mercury down to 3°, *viz.* 29° below the freezing point, when the atmoſphere

atmosphere was somewhat hotter than temperate, and that without blowing upon the thermometer.

When the ether is very good, *viz.* is capable of dissolving elastic gum, and the thermometer has a small bulb, not above twenty drops of ether are required to produce this effect, and about two minutes of time; but when the ether is of the common sort, a greater quantity of it, and a longer time, is necessary to be employed, though at last the thermometer is brought down very nearly as low by this as by the best sort of ether.

In order to freeze water by the evaporation of ether, I take a thin glass tube about four inches long and about one-fifth of an inch in diameter, hermetically closed at one end, and put a little water in it, so as to fill about half an inch length of it, as is shewn at CB in the figure. Into this tube a slender wire H is also introduced, the lower extremity of which is twisted in a spiral manner, and serves to draw up the ice, when formed. Things being thus prepared, I hold the glass tube by its upper part A with the fingers of the left hand, and keep it continually and gently turning round its axis, first one way, and then the contrary; whilst with the right hand I hold the phial containing the ether in such a manner as to direct the stream of ether on the outside of the tube, and a little above the surface of the water in it. The capillary aperture D should be kept almost in contact with the surface of the tube that contains the water. Continuing this operation for two or three minutes, the water will be froze as it were in an instant; since it will appear to become opaque at the bottom B, and the opacity will ascend at C in less than half a second of time, which exhibits a beautiful appearance. This congelation, however, is only superficial, and in order to congeal the whole quantity of wa-

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ter, the operation muſt be continued one or two minutes longer; after which the wire H will be found to be kept very tight by the ice. Now the bottle with the ether is left upon a table or other place, and to the outſide of the glaſs tube the hand muſt be applied for a moment, in order to ſoften the ſurface of the ice, which adheres very firmly to the glaſs, and then pulling the wire H out of the tube, a ſolid and hard piece of ice will come out, faſtened to its ſpiral extremity.

Inſtead of the wire H ſometimes I put a ſmall thermometer into this tube ſo as to have its bulb immerſed in the water. With this thermometer I have obſerved a very remarkable phenomenon, which ſeems to be not explicable in the preſent ſtate of knowledge concerning heat and cold. This is, that water will freeze in the winter with a leſs degree of cold than it will in the ſummer, or when the weather is hotter: for inſtance, in the winter the water in the tube AB will freeze when the thermometer is about 30°; but in the ſummer, or even when the temperature of the atmoſphere is about 60°, the quickſilver in the thermomer muſt be brought ten or fifteen, or even more, degrees below the freezing point, before the water which ſurrounds the ſaid thermometer will be converted into ice, even ſuperficially; hence it appears, that in the ſummer time a greater quantity of ether and longer time is required to freez a given quantity of water than in the winter, not only becauſe then a greater degree of heat is to be overcome, but principally becauſe in the ſummer a much greater degree of cold muſt be actually produced before the water that is kept in it will aſſume a ſolid form. When the temperature of the atmoſphere has been about 40°, I have froze a quantity of water with an equal weight of good ether, but at preſent,

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being ſummer, between two and three times the quantity of the ſame ether muſt be uſed to produce the ſameeffect.

There ſeems to be ſomething in the air which, beſides heat, interferes with the freezing of water, and perhaps of all fluids, though I cannot ſay from experience whether the above mentioned difference between the freezing of water in winter and ſummer, takes place with other fluids, as milk and other animal fluids, oils, wines, &c.

The proportion between the quantity of the ether and of the water that may be frozen by it, ſeems to vary according to the quantity of water; for a larger quantity of water ſeems to require a proportionably leſs quantity of ether than a ſmaller quantity of water, ſuppoſing that the water is contained in cylindrical glaſs veſſels; for I have not tried whether a metal veſſel inſtead of a glaſs one, and whether ſome other ſhape beſides the cylindrical, might not facilitate the congelation. In the beginning of the ſpring I froze about a quarter of an ounce of water with nearly half an ounce weight of ether, the apparatus being larger, though ſimilar to that deſcribed above.

Now as the price of ether, ſufficiently good for the purpoſe, is generally between eighteen pence and two ſhillings *per* ounce, it is plain, that with leſs than two ſhillings a quarter of an ounce of ice, or ice cream, may be made in every climate, and at any time, which may afford great ſatisfaction to thoſe perſons, who living in places where no natural ice is to be had, never ſaw or taſted any ſuch delicious refreſhments.

When a ſmall piece of ice, for inſtance, of about ten grains in weight, is wanted, the neceſſary apparatus is very ſmall, and the expence of the ether not worth mentioning. I have a ſmall box, which is four inches and a half long, two inches broad, and one inch and a half deep, which contains all the apparatus

ratus neceſſary for this purpoſe, *viz.* a bottle capable of containing about one ounce of ether, two pointed tubes (in caſe that one ſhould break) a tube in which the water is to be frozen, and the wire. With the quantity of ether contained in this ſmall and very portable apparatus, the experiment, when carefully performed, may be repeated about ten times. A perſon who wiſhes to perform ſuch experiments in hot climates, and in places where ice is not eaſily procured, requires only a large bottle of ether, beſides the ſmall apparatus deſcribed above.

It is a known fact, that the moment a quantity of water becomes ice, a thermometer kept immerſed in it, riſes a few degrees, and accordingly this is obſerved in our experiment, *viz.* the mercury of the thermometer, which is immerſed in the water of the tube AB, will ſuddenly riſe, ſometimes as much as ten degrees, when the water becomes firſt opaque. Electrization increaſes very little the degree of cold produced by the evaporation of ether. Having thrown the electrified, and alſo the unelectrified, ſtream of ether upon the bulb of a thermometer, the mercury in it was brought down two degrees lower in the former than in the latter caſe.

As various perſons may, perhaps, be induced by this paper to repeat ſuch experiments, and as ether is a fluid which can with difficulty be preſerved, it may be uſeful to mention, that a cork confines ether in a glaſs bottle much better than a glaſs ſtopple, which it is almoſt impoſſible to grind ſo well as intirely to prevent the evaporation of ether. When a ſtopple, made very nicely out of a uniform and cloſe piece of cork, which goes rather tight, is put upon a bottle of ether, the ſmell of that fluid cannot be perceived through it; but I never ſaw a glaſs ſtopple that could produce the ſame effect. By opening

ing the bottle very often, or by long keeping, the cork becomes looſe, in which caſe it muſt be changed; and thus ether, ſpirit of wine, or any fluid, excepting thoſe which corrode cork, may be preſerved.

I ſhall now deſcribe a method of purifying vitriolic ether, which is very eaſy and expeditious, though not very profitable: this method I learned of Mr. WINCH, Chemiſt, in the Hay-market. Fill about a quarter of a ſtrong bottle with common ether, and upon it pour about twice as much water, then ſtop the bottle, and give it a ſhake, ſo as to mix for a time the ether with the water. This done, keep the bottle without motion, and with the mouth downwards, till the ether is ſeparated from the water and ſwims over it, which requires not above three or four minutes of time; then open the bottle, and keeping it ſtill inverted, let the greateſt part of the water come out very gently; after this the bottle being turned with the mouth up-wards, more water muſt be poured in it, and in ſhort the ſame operation muſt be repeated three or four times. Laſtly, all the water being ſeparated from the ether by decanting it with dexterity, the ether will be found to be exceedingly pure. By this means I have purified common vitriolic ether, which could not affect elaſtic gum, and have reduced it into ſuch a ſtate as that elaſtic gum was eaſily diſſolved by it. Indeed this purified ether appeared by every trial to be purer than I ever ſaw it, even when made after the beſt uſual method, and in the moſt careful manner. The only inconvenience attending this proceſs is, that a vaſt quantity of ether is loſt. Not above three or four ounces of a pound of common ether remain after the purification. As the greateſt part of the ether is certainly mixed with the water that is uſed in the proceſs, it may perhaps be worth while to put that water into a retort, and

to diſtil the ether from it, which muſt come ſufficiently pure for common uſe.

It is commonly believed, that water combines with the pureſt part of ether, when thoſe two fluids are kept together; whereas, by the above deſcribed proceſs, the contrary is eſtabliſhed: perhaps when ether is kept in contact with water for a long time, the pureſt part of it may appear to be loſt, becauſe the ether may be combined with, and may retain ſome water in itſelf, at the ſame time that the water combines with and retains ſome ether, whereas the caſe may be different when the ether is quickly waſhed in water, and is immediately after ſeparated from it: but in reſpect to this I have yet not made any experiments, ſo as to be able to decide the matter.

II. *Experiments relating to the expanſion of mercury.*

THE difficulty and uncertainty attending the various methods hitherto propoſed for inveſtigating the expanſion of quickſilver, or its increaſe of bulk when rarified by a given degree of heat, determined me to contrive ſome method by which this purpoſe might be effected with more certainty and preciſion. After various experiments I hit upon the following method, which to me ſeems both new and capable of great accuracy, though in this I may be deceived.

Firſt, having blown a ball to a capillary tube, ſuch as are commonly uſed for thermometers, I weighed it, and found that this empty thermometer was equal to 79,25 grains. This empty glaſs previous to its being weighed was rendered as perfectly

fectly clean as possible, which is a necessary precaution in this experiment, which depends upon a very great accuracy of weight. Then I introduced some mercury into the stem of this thermometer, taking care that none of it entered the ball, and, by adapting a scale of inches to the tube, observed that 4,3 inches length of the tube was filled with the mercury. The thermometer was now weighed again, and from this weight, the weight of the glass found before being subtracted, the remainder, *viz.* 0,24 gr. shewed the weight of so much quicksilver as filled 4,3 inches of the tube. Now the ball of the thermometer, and also part of the tube, were intirely filled with quicksilver: then, in order to find out the weight of the mercury contained in it, the thermometer was weighed for the last time, and from this weight the weight of the glass being subtracted, the remainder, *viz.* 3205 grs. shewed the weight of the whole quantity of quicksilver contained in the thermometer.

By comparison with a graduated thermometer in hot and cold water, I made a scale to the new thermometer according to FAHRENHEIT's, and by applying a scale of inches found, that the length of 20° in this scale was equal to 1,33 inch. But 0,24 gr. was the weight of so much mercury as filled 4,3 inches length of the tube; therefore, by the rule of proportion it will be found, that the weight of so much quicksilver as fills 1,33 inch of the tube, *viz.* the length of 20° is equal to 0,0742 gr. nearly, and that the weight of so much quicksilver as fills the length of the tube that is equivalent to one degree, is equal to 0,00371 gr. Now it is clear, that the weight of the whole quantity of quicksilver contained in the thermometer is to the weight of so much quicksilver as fills the length of one degree in the tube, as the bulk of the whole quantity of quick-

ſilver in a given degree of heat, to the increaſe of bulk, that the ſame whole quantity of quickſilver acquires when heated of but 1°; *viz.* 32,05 grs. is to 0,00371 gr. as 1 is to 0,0011 +; ſo that by this experiment it appears, that 1° of FAHRENHEIT's thermometer increaſes the bulk of mercury not above $\frac{11}{100000}$ths parts. In this proceſs a ſmall deviation from mathematical exactneſs is occaſioned by the ſmall difference of weight between the quickſilver of the tube when firſt weighed and when it is afterwards heated to 1°; but by an eaſy calculation it will be found, that this difference is ſo exceedingly ſmall as not to be perceived by our exacteſt weighing and meaſuring inſtruments.

For clearneſs ſake I ſhall ſubjoin the calculation of the above related experiments, diſencumbered from words. Here the decimals are not computed to a very large number, that being unneceſſary for this purpoſe.

Weight of the glaſs, - - - - -	79,25 grs.
Weight of ſo much quickſilver as filled 4,3 inches length of the tube, - - -	0,24 grs.
Weight of the whole quantity of quickſilver contained in the thermometer, - -	32,05 grs.
Length of the tube equal to 20°, - -	1,33 inch.

$4,3 : 0,24 :: 1,33 : 0,0742 = 20°$

$20° : 0,0742 :: 1 : 0,00371$

$32,05 : 0,00371 :: 1 : 0,00011 + =$ to the expanſion occaſioned by one degree of heat.

Having repeated this experiment with other thermometers, and by ſimilar calculations, each proceſs gave a reſult little different from the others, which irregularity is certainly owing to the imperfection of my ſcales, which are not of the niceſt ſort: but taking a mean of various experiments it appears, that

that 1° of heat, according to FAHRENHEIT's thermometer, increases the bulk of a quantity of quicksilver of $\frac{9}{100000}$ths parts, *viz.* if the bulk of a quantity of quicksilver in the temperature of 50° is equal to 100,000 cubic inches, the bulk of the same quantity of quicksilver in the temperature of 51° will be equal to 100,009 cubic inches.

It is almost superfluous to mention, that the cavity of the tubes employed for these experiments, must be perfectly uniform throughout. The scales to be used for this method should be so exact as to be turned by the hundredth part of a grain when charged with about half an ounce weight.

From these observations the method of graduating, or of determining the length of a degree in a new thermometer, is easily deduced, the only requisites for the calculation being the weight of a quantity of quicksilver, which fills a known length of the tube, and the weight of the whole quantity of quicksilver contained in the thermometer when filled. Suppose, for instance, that in making a new thermometer it be found, that the weight of so much quicksilver as fills five inches length of the tube is equal to ten grains, and that the weight of the whole quantity of quicksilver contained in the thermometer weighs 300 grains. It is plain, that if the whole quantity of quicksilver weighs 300 grs. $\frac{9}{100000}$ths parts of it must weigh 0,027 gr. But the weight of so much mercury as fills five inches of the tube is equal to 10 grains; therefore, 0,027 gr. weight of quicksilver must fill 0,0133 inch of the tube, and this is equal to the length of 1°, or the double, treble, &c. of it is equal to two, three, &c. degrees.

By this means the scale may be made; that is, it may be divided into degrees, but the numbers cannot be added to them without finding which of those degrees corresponds with the

freezing point or boiling point. Either the point of boiling or freezing may be found by experiment, or any other point may be aſcertained by compariſon with another thermometer, and then the other degrees are nominated accordingly.

III. *Deſcription of a thermometrical barometer.*

THE determination of the various degrees of heat ſhewn by boiling water under different preſſures of the atmoſphere, has been attempted by various perſons, but it was lately completed by the accurate and numerous experiments of Sir GEORGE SHUCKBURGH, member of this Society. His valuable paper is inſerted in the LXIXth vol. of the Phil. Tranſ. Upon conſidering this paper, I thought it poſſible to conſtruct a thermometer with proper apparatus, which, by means of boiling water, might indicate the various gravity of the atmoſphere, *viz.* the height of the barometer. This thermometer, together with the ſuitable apparatus, might, I thought, be packed into a ſmall and very portable box, and I even flattered myſelf, that with ſuch an inſtrument the heights of mountains, &c. might perhaps be determined with greater facility than with the common portable barometer. My expectations are far from having been diſappointed, and although the inſtrument which I have hitherto conſtructed has various defects, I have, however, thought of ſome expedients which will undoubtedly render it much more perfect; I ſhall then preſent to this Society a more particular account of it, and alſo of the experiments which I intend to make with it. The inſtrument in its preſent ſtate conſiſts of a cylindrical tin veſſel, about two inches in diameter and five inches high, in which veſſel the water is

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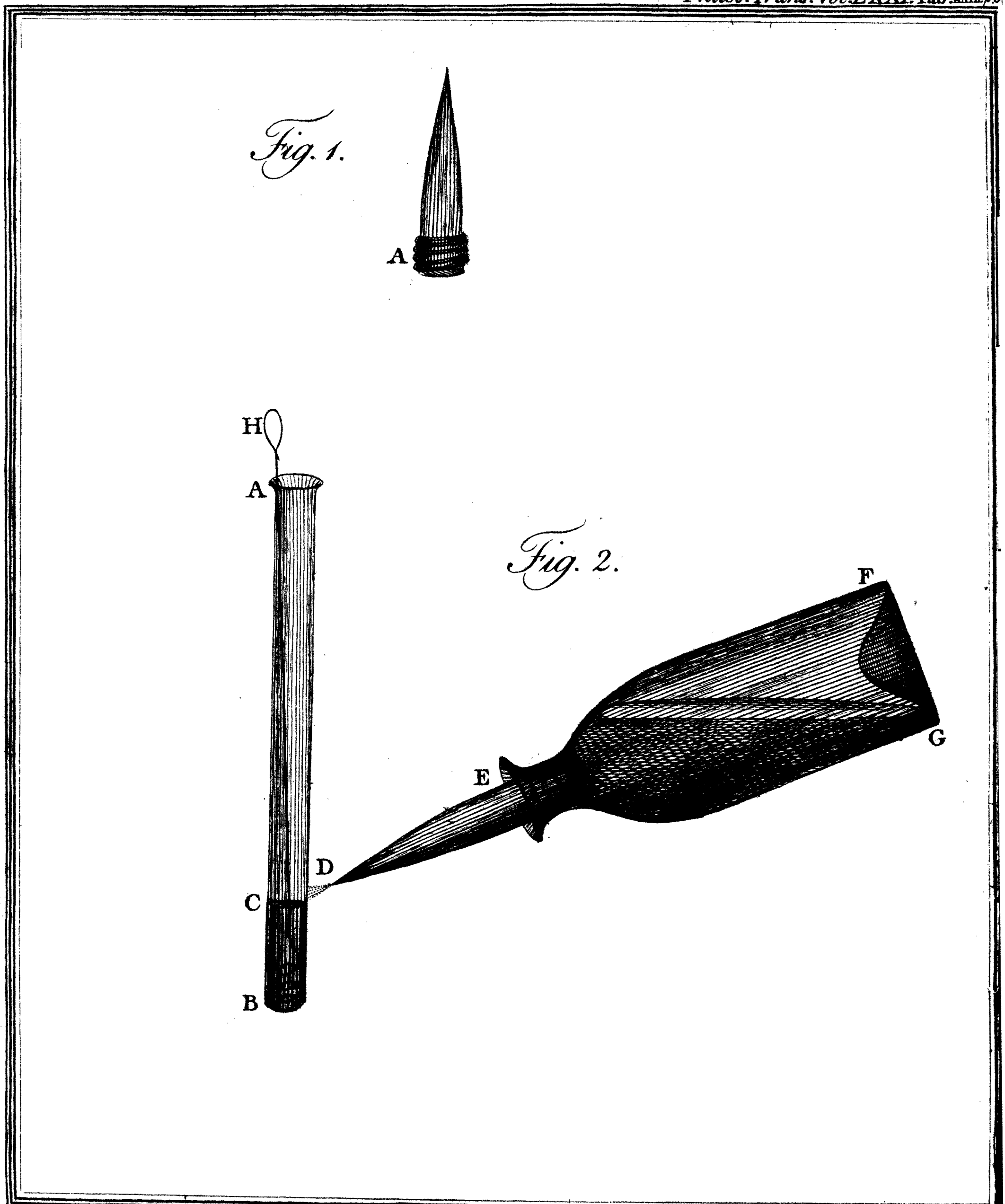

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contained, which may be made to boil by the flame of a large wax candle. The thermometer is faſtened to the tin veſſel in ſuch a manner as that its bulb may be about one inch above the bottom. The ſcale of this thermometer, which is of braſs, exhibits on one ſide of the glaſs tube a few degrees of FAHRENHEIT'S ſcale, *viz.* from 200° to 216°. On the other ſide of the tube are marked the various barometrical heights, at which the boiling water ſhews thoſe particular degrees of heat which are ſet down in Sir G. SHUCKBURGH'S table. With this inſtrument the barometrical height is ſhewn within one-tenth of an inch. The degrees of this thermometer are ſomewhat longer than one-ninth of an inch, and conſequently may be ſubdivided into many parts, eſpecially if a nonius is uſed. But the greateſt imperfection of this inſtrument ariſes from the ſmallneſs of the tin veſſel, which does not admit a ſufficient quantity of water: and I find, that when a thermometer is kept in a ſmall quantity of boiling water, the quickſilver in its ſtem does not ſtand very ſteady, ſometimes riſing or falling even half a degree; but when the quantity of water is ſufficiently large, for inſtance is ten or twelve ounces, and is kept boiling in a proper veſſel, its degree of heat under the ſame preſſure of the atmoſphere is very ſettled.